REVIEW OF FISHERIES BIOLOGY OF *SCOMBEROMORUS* AND *ACANTHOCYBIUM* SPECIES IN THE WESTERN INDIAN OCEAN (FAO AREA 51)

M. S. M. Siddeek

Department of Fisheries Science and Technology
College of Agriculture
Sultan Qaboos University
Box 34
Al-Khod 123
Sultanate of Oman

INTRODUCTION

The seerfish group *(Scomberomorus and Acanthocybium* species) contributes less than 2% to the total landings from the western Indian Ocean (FAO Area 51, Fig. 1) (FAO 1994). Although its contribution is minor in quantity when compared with the landings of other major fish groups, it is considered as the prime fish in almost all the countries bordering this area. Seerfish fetch a higher price per kilogram than any other marine fin-fish landed in these countries. It is also a valuable export product in some of these countries (*e.g*., Oman).

The high demand appears to have triggered over-exploitation of some stocks living in this region. Therefore, research studies are needed to assess these stocks to formulate appropriate management and development plans. Research studies in this region have focussed on the prime species, *Scomberomorus commerson* (Lacepede, 1800), and very little research effort is spent on the other species (Anon., 1995a). Primarily length-based stock assessment methods have been used (*e.g.*, Kedidi *et al.*, 1993; Pillai *et al.*, 1993).

This review summarises current knowledge of seerfish fisheries biology, fisheries, recruitment, growth, mortality, gear selectivity, and stock assessment in Area 51. In particular, it addresses the problems associated with the application of length-based stock assessment methods to migratory fish. It also identifies the stock assessment objectives that need to be addressed.

FISHERIES BIOLOGY

Taxonomy

Three species of large pelagic fish belonging to the family Scombridae and genus *Scomberomorus (Scomberomorus commerson* (Lacepede, 1800), *Scomberomorus guttatus* (Bloch & Schneider, 1801), and *Scomberomorus lineolatus* (Cuvier, 1831)) are caught in commercial quantities in the Western Indian Ocean. *Acanthocybium* is a closely related genus to *Scomberomorus* and is represented by a single species, *Acanthocybium solandri* (Cuvier, 1831), which is also reported in the catches, but in insignificant quantities.

Distribution

The distribution of *S. commerson* extends from the Red Sea and the east coast of Africa, and through Mauritius, the Arabian Sea, and the Gulf (Persian Gulf/Arabian Gulf), the coasts of India, Sri Lanka, Myanmar, Thailand, Malaysia, Indonesia, Philippines, Australia, Papua New Guinea, further eastwards to Fiji, New Caledonia, Solomon Islands, Guam, and further northwards to Taiwan and Japan. It has been introduced to coastal waters of Israel and Lebanon. in the eastern Mediterranean through the Red Sea (Bal and Rao, 1990; Anon., 1995a).

The distribution of *S. guttatus* is limited to the southeast coast of Africa, the Arabian Sea, the Gulf, Madagascar, Seychelles, the coasts of India, Sri Lanka, Andaman Islands, Bangladesh, Myanmar, Thailand, Cambodia, Malaysia, Indonesia, Philippines, Brunei Darussalam, China, Vietnam, Taiwan, and Hong Kong.

The range of distribution of *S. lineolatus* is much narrower than the other two species. It is found in east African waters (*e.g.*, Natal coast of South Africa), the coasts of India, Sri Lanka, Bangladesh, Myanmar, Thailand, Malaysia, and Indonesia.

Unlike the three *Scomberomorus* species, which are primarily coastal, *A. solandri* is an oceanic species occurring offshore beyond the continental shelf. *A. solandri* has a world-wide distribution, but its contribution to the total seerfish catch is small. It is found in waters off almost all countries reported above and, in addition, in waters off a number of countries surrounding the Mediterranean Sea, the Gulf of Mexico, and in the tropical and subtropical waters of the Pacific (Anon., 1995a).

Thus, the seerfish production in Area 51 is dominated by *S. commerson,* followed by *S. guttatus, S. lineolatus, and A. solandri* (Table 1).

***Table 1**. Nominal catches (t) of* Acanthocybium *and* Scomberomorus *fishes in FAO Area 51.*

Species/Area	***1984***	***1985***	***1986***	***1987***	***1988***	***1989***	***1990***	***1991***	***1992***	***1993***
Acanthocybium solandri:										
France	-	-	-	-	-	-	-	1	9	-
India	0	58	0	0	-	-	79	-	30	28
Seychelles		1	6	3	3	2	4	8	3	3
Total	0	59	6	3	3	2	83	9	42	31
***Scomberomorus commerson*:**										
Bahrain	221	141	290	294	189	242	92	131	114	77
India	9,329	10,769	14,547	12,757	10,000	11,000	8,921	11,298	11,000	13,000
Iran	618	735	697	1,062	1,000	2,510	3,379	3,717	3,328	4,095
Israel	-	-	-	-	40	-	-	-	-	-
Kenya	55	57	60	82	52	71	94	110	75	46
Kuwait	16	3	70	11	23	13	7	2	33	35
Oman		20,270	14,316	25,378	27,834	11,111	7,638	3,609	3,517	3,148
Pakistan	7,148	7,582	8,010	8,088	10,497	6,834	5,941	6,272	12,133	12,252
Qatar	304	289	124	114	143	213	562	42	766	636
South Africa	199	242	13	11	89	85	10	23	17	-
Sri Lanka	3,299	3,475	3,574	3,698	3,842	3,899	3,314	3,916	3,824	3,769
U.A.E.	5,000	4,000	6,180	5,500	6,000	5,933	5,933	5,620	5,789	5,630
Yemen	3,115	2,351	2,673	2,782	2,273	2,273	2,369	2,629	2,551	2,743
Total	29,304	49,914	50,554	59,777	61,982	44,184	38,260	37,369	43,147	45,431
Scomberomorus guttatus										
India	10,913	13,628	8,393	8,030	7,000	8,000	9,144	11000	10,886	15,317
Iran	926	490	465	707	667	1,673	2,254	2,479	2,218	1868
Kuwait	14	11	6	105	30	89	124	2	92	124
Total	11,853	14,129	8,864	8,842	7,697	9,762	11,522	13,481	13,196	17,309
***Scomberomorus lineolatus* :**										
India	14	4	2,005		72	186	461	700	500	500
Total	14	4	2,005	0	72	186	461	700	500	500

Source: FAO yearbook, Fishery Statistics-Catches and Landings, vols. 75 and 76.

Food and Feeding Habits

The adults of the three *Scomberomorus* species are carnivorous and predominantly piscivorous, feeding on small pelagic fish such as anchovies and sardines, and occasionally squids and penaeid shrimps (McPherson, 1987; Anon., 1995a). S. *commerson* preys on a variety of pelagic fish species, whereas *S. guttatus and* S. *lineolatus* restrict themselves to only a few of them. Adult *S. lineolatus* in the Zanzibar Channel were reported to be feeding primarily on sardine (Chisara, 1986). Since their gillrakers are rudimentary and few, juveniles are forced to feed on larger organisms such as larval and juvenile pelagic fishes. Crustaceans become secondary food items for juvenile *Scomberomorus.* Interestingly, juveniles of *S. commerson* have a cannibalistic tendency (Bal and Rao, 1990).

There are no recorded data on the feeding behaviour of larval and postlarval stages of these three species. However, diet composition analysis of larval, post-larval and juvenile king mackerel *(Scomberomorus cavalla)* and Spanish mackerel *(S. maculatus)* off the southeastern United States indicated that the larval and post-larval diets consisted mostly of early-stage fishes (Finucane *et al.*, 1990).

Table 2. *Size and age at first maturity of* Scomberomorus *species. Values refer to females unless stated otherwise in the "Remarks'. (TL = total length, FL= fork length*).

Species	*Length (cm)*		*Age (yrs)*		*Remarks*
	Range	*Center value*	*Range*	*Center value*	
S. commerson	70.1-80.0 TL	75.0 TL			Palk Bay, Gulf of Mannar, and southeast Arabian Sea (Devaraj, 1983)
			2-3		Palk Bay, Gulf of Mannar, and southeast Arabian Sea (Devaraj, 1981)
	75-80 FL			1*	Oman (Dudley *et al.*, 1992)
		85.0 FL			southern Red Sea (Bouhlel, 1985)
		50.0 TL			Unsexed, Kenyan coastal waters (Nzioka, 1991)
	55.0-64.0 FL				East African waters (Williams, 1964)
		65.4 FL			Papua New Guinea (Lewis *et al.*, 1974)
		79.0 FL			East of Queensland stock (McPherson, 1993)
		80.0 FL			northern stock (op. cit.)
		70 FL			Female, unspecified area Collette and Nauen,1983)
		65 FL			Male, unspecified area Collette and Nauen,1983)
S. guttatus		40.0 TL	1.7		Palk Bay and the Gulf of Mannar (Devaraj, 1987)
	48.0-52.0 TL				India (Bal and Rao, 1990)
S. lineolatus		70.0 TL	2		Gulf of Mannar and Palk Bay (Devaraj, 1986
			2-3		Palk Bay, Gulf of Mannar, and southeast Arabian Sea (Devaraj, 1981)

- Center value refers to mean, median, mode, or a single estimate.

A. solandri is also carnivorous, being an oceanic species, and feeds on a number of oceanic pelagic fishes such as scombrids, porcupine fishes, flying fishes, herrings and pilchards, scads, lanternfishes and squids (Anon., 1995a).

Migration and Shoaling Behaviour

Seerfish appear to undertake lengthy coastal migrations. However, there are no specific migration studies reported in any countries bordering Area 51. Tagging experiments undertaken on *S. commerson* off Queensland (Australia) indicated seasonal north-south migration as well as onshore-offshore spawning migration (McPherson, 1981). Mark-recapture data on king mackerel *(S. cavalla)* in the Gulf of Mexico indicated a large resident population throughout the year in the northwest Gulf and that smaller migrants from south Florida and Mexico mix with the resident stock during the summer (Fable *et al.*, 1987). It is likely that a two-stock situation similar to this may occur among neighbouring countries having large stock biomass (*e.g.* Pakistan, Iran, Oman, and U.A.E.).

Based on fishermen's experiences and seasonal size composition of catches in Oman, the migration pattern of *S. commerson* in the eastern Arabian Sea, the Gulf of Oman, and the Gulf was constructed (Al-Mamry, 1989; Anon., 1995b). In the early spring, fish appear to move into the Gulf from the eastern Arabian Sea and Indian Ocean for spawning. This season lasts for a period of one to four months. The return migration of spent fish from the Gulf to the Arabian Sea occurs by the end of summer. On their return journey, fish spend approximately three months near the shore of Sur in the Gulf of Oman. They may stay longer if there is a high abundance of sardine and cool water temperatures. Thus, fishermen's stories implicitly associate fish abundance with the strength of monsoon upwelling. There is also a third migration, in which very large fish from offshore move to nearshore water. This occurs just before the spawning migration period.

Table 3. **Common names of *Scomberomorus* and *Acanthocybium* fishes in FAO Area 51. (E= English, A=Arabic, S=Swahili, F=Farsi)**

	S. commerson	***S guttatus***	***S. lineatus***	***A. solandri***
South Africa	King mackerel (E)		Queen mackerel (E)	Wahoo (E)
Kenya	Nguru (S) Nguru-mtwane (S)			
Saudi Arabia	Derak (A) Kanad (A)			
Yemen				
Oman	Kanad (A)	Kanad (A) Khabbat (A)*	Khabbat (A)*	Kanad Zanjebari (A)
U.A.E.	Kanad (A) Khabbat (A)*			
Qatar.	Kanad (A)	Kanad (A)		
Bahrain	Kanad (A)			
Kuwait	Kanad (A)			
Iran			Ghobad (F) Sheer (F)	
Pakistan				
India	Seerfish (E) Barred Spanish mackerel (E) King seer (E)	Seerfish (E) Spotted Spanish mackerel (E) Spotted seer (E)	Streaked Spanish mackerel (E) Streaked seer (E)	
Sri Lanka	Barred Spanish mackerel (E) Striped seer (E)	Spotted Spanish mackerel (E)	Streaked Spanish mackerel (E)	
Food and Agriculture Organisation (FAO)	Narrow-barred Spanish mackerel (E) Narrow barred mackerel (E)	Spotted Spanish mackerel (E) Indo-Pacific king mackerel (E)	Streaked seerfish (E)	Wahoo (E)
Indo-Pacific Tuna Programme (IPTP)	Narrow-barred king mackerel (E)	Indo-Pacific king mackerel (E)		

Khabbat is usually referred to small seerfish

Following the peak summer spawning, newly recruited cohort of *S. commerson* starts to move south from the Gulf along the coast into the Arabian Sea. This is evidenced by the seasonal increase in mean length of fish in the catch from north (Musandum) to south (Batinah Coast) in Oman during the early months of the fishing season (Anon., 1995b).

Studies in Indian waters indicated that *S. commerson* move in small shoals, but during the peak fishing season fairly dense shoals may occur. Migration of *S. guttatus* is less extensive when compared to *S. commerson* (Anon., 1995a), and its shoaling behaviour has not been studied. On the other hand, *S. lineolatus* shoals appear to be very large and composed of fish belonging to a single year-class (Bal and Rao, 1990).

A. solandri frequently move individually in the oceanic waters and sometimes form loose aggregations rather than compact schools (Anon., 1995a).

Table 4. **Growth (L∞, K, to) parameters and the largest size of fish (length / weight) in the catches of *Scomberomorus* and *Acanthocybium* species. Values refer to unsexed fish unless stated otherwise in the 'Remarks". (FL= fork length, TL= total length**

Species	L_∞ *(cm)*	*K(yr^{-1})*	*t_0 (yr)*	*Largest size*	*Remarks*
S. commerson	146 FL	0.37			Sri Lanka, 1986-1987 data, ELEFAN (Dayaratne, 1989b)
	208.1 TL	0.18	-0.16	193.6 cm TL 33 kg	South and south west India, 1967-1969 data, Rafail's iterative method of fitting on length modes determined by Petersen's method and length at otolith age (Devaraj, 1981)
	146 TL	0.78			Southwest India, 1989-91 data modal progression analysis (Pillai *et al.*, 1993)
	177.5 FL	0.38	-0.23		South east India, Ford-Walford plot (Thiagarajan, 1989)
	226 FL	0.21	-0.85	200 cm FL	Oman, ELEFAN and graphical method (Dudley *et al.*, 1992)
	193.6 FL	0.29	-0.678		Oman, least square fitting on modal lengths from Bhattacharya method (Dudley *et al.*, 1992)
	138.3 FL	0.36	-1.16		Oman, least square fitting on length at otolith age (Dudley *et al.*, 1992)
	131.2 FL	0.61	-0.438		Oman, least square fitting on the combined set of otolith and length frequency modal lengths (Dudley *et al.*, 1992)
	break point = 1.68 years (at 100.2 cm FL Segment 1: length = 36.21 age + 39.22 Segment 2: length = 4.7 age + 92.32				Oman, segmented regression fitting on the combined set of otolith and length frequency modal lengths (Dudley *et al.*, 1992)
	164 FL	0.34			Oman, 1987-89 data, ELEFAN (Dudley and AghanashinIkar, 1989)
	182 FL	0.3	-0.7		Oman, least square fitting on modal lengths of the catch from Bhattacharya method (Bertignac and Yesaki, 1993)
	183.6 TL	0.26			Saudi Arabian Gulf, 1 86-1992 data, modal lengths of the catch from Bhattacharya method used in VONBER programme (Sparre *et al.* 1989) and average growth parameters estimated by ELEFAN (Kedidi *et al.*, 1993)
S. commerson	153.3 TL	0.38	-0.26		Saudi Arabian Red Sea, 1985 - 1986 data, Gulland and Hoolt plot on modal lengths of the catch from Bhattacharya method (Kedidi and Abushusha, 1987)
	151 TL	0.21			Djibouti, Ford Watford plot (Bouhlel, 1985)
	230.3 FL	0.12	0.01		Gulf of Aden, Yemen (Edwards *et al.*, 1985)
				230 cm FL	Gulf of Aden, Yemen (Edwards and Shaher, 1991)
				200 cm FL	South Africa (Torres, 1991)
S. guttatus	127.8 TL	0.18	-0.47	70.5 cm TL 2.07 kg	South and southwest India, 1967-1969 length and otolith annuli data, Rafia's iterative method of fitting (Devaraj, 1981
				76 cm FL	Female, unspecified area (Collette and Nauen,1983)
S. lineolatus	144.7 TL	0.22	-0.51	98 cm TL 4.553 kg	Female, south and southwest India,1967 - 1969 length and otholit annuli data, Bagenal's least squares method of fitting (Devaraj, 1981
	168.3 TL	0.18	-0.66	94 cm TL 4.25 kg	Male, south and southwest India,1967 - 1969 length and otholit annuli data, Bagenal's least squares method of fitting (Devaraj, 1981
A. solandri	158.5 FL	0.35			St. Lucia, West Indies, 1982-83 data, mean values from 1982 and 1983 growth parameter estimates by ELEFAN (Murray and Sarvay, 1987)
				200 cm FL	Female, South Africa (Torres, 1991)

Table 5. **Length (cm) at age (year) of *Scomberomorus* species in the FAO Area 51. Values refer to unsexed fish unless stated otherwise in the "Remarks". (TL = total length, FL fork length).**

Species /Age	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Remarks*
S. commerson	45.2 FL	76.3	97.9					Sri Lanka, growth curve (Dayaratne, 1989b)
	40.2 TL	72.6	99.5	118.6				India, Petersen's method (Devaraj, 1981)
	80 TL	113	132.2	141	142	158		India, growth curve (Pillai *et al.*, 1993)
	70-80 FL	100-110						Oman, otolith ageing (Dudley *et al.*, 1992)
S. guttatus	36.9 TL	53.2	64					India, Petersen's method (Devaraj, 1981)
	33.7 TL	51.3	64.1	73.8	81.1	87.2	93.3	India (Rao, 1978)
S. lineolatus	35 TL	71.3	83.5	96.5				India, Petersen's method (Devaraj, 1981)

Unit Stock

Prior to stock assessment, the unit stock and its boundary should be defined. Stock assessment of migratory large pelagic fish often poses problems because of the stock being shared by two or many countries. This appears to be true for the seerfish in Area 51.

Using an electrophoretic technique, Shaklee (1 987) identified several genetically different *S. commerson* stocks in north Australian and Papua New Guinea waters and suggested that the fish stock in Torres Strait may be a mix of many sub-stocks. Shaklee and Shaklee (1990) carried out similar studies on *S. commerson* from Djibouti, Oman and U.A.E., and found small genetic differences among stocks in these three places.

Although *S. commerson* stocks in Oman and U.A.E. are reported to be genetically different, it is very likely that both stocks are shared by the two countries or many more because of along-shore long-distance migration. It is unlikely that the stock parameters among the sub-stocks within the larger unit will differ significantly. Therefore, for stock assessment purposes, the sub-stocks in the north-eastern Arabian Sea, the Gulf of Oman, and the Gulf may be grouped under one unit stock (*i.e.*, a management unit (Gulland, 1983)). Similarly, the stocks in the northwestern Arabian Sea and the Red Sea may be grouped under another unit stock.

Reproduction

Spawning Season

Spawning seasons of seerfish vary in different areas due to varying oceanographic conditions.

S. commerson

Based on gonad index and ova diameter analyses, Devaraj (1983) determined an extended spawning period of January-September, with a peak in April-May in Palk Bay, Gulf of Mannar and the southeast Arabian Sea. The spawning period in Iranian waters was reported to be August-October (Anon., 1995b). Based on otolith-derived ages, Dudley *et al.* (1992) determined the fertilisation period to be 15 April-15 July, with a mean of 1 July in Omani waters. Based on the gonad index, Kedidi and Abushusha (1987) and Kedidi *et al.* (1993) reported a peak spawning period of April-June in the Red Sea and the Gulf. Bouhlel (1985) recorded a peak spawning period of April-July for the stock off the coast of Djibouti. Nzioka (1991) observed year-round spawning activity with peaks in May and October in Kenyan coastal waters. He associated these peaks with monsoon rainfall. Williams (1964) observed year-round spawning in east African waters. McPherson (1993) reported the occurrence of a reproductive peak in October and November in the Queensland east coast stock.

It appears that in Area 51 the prime species, *S. commerson,* spawns year-round, with two peaks, a major one during late spring to summer (April-July) and a minor one in autumn (September - November). A hypothesis of protracted spawning is justifiable, at least in the Gulf of Oman, because of the year-round plankton and small pelagic fish production in this area (Stirn, unpublished notes, 1994). The author's personal observation on the size frequency of *S. commerson* landed in Musandum (Oman) in early April 1995 supports the view of a minor spawning peak in autumn in the Gulf. The size frequency showed the presence of a small peak at 55-60 cm fork length (FL) (Figure 2). Following Dudley *et al.* (1992), this length interval corresponds to a fish group of approximately 6-month of age; thus, this group may have been born in October-.November. The two spawning peaks appear to be synchronised with the two seasonal monsoons to exploit the post-monsoon plankton and small pelagic fish production in coastal waters (Siddeek *et al.*, unpub. ms.).

Table 6. **Length-weight relationship in *Scomberomorus* and *Acanthocybium* species in FAO Area 51. Values refer to unsexed fish unless stated otherwise in the "Remarks". (W = a Lb , where, W = weight in kg, L = length in cm, and 'a' and 'b' are constants; TL = total length, FL = fork length).**

Species	*Type of Measurement*	*a*	*b*	*Remarks*
S. commerson	TL	$9.61 * 10^{-3}$	2.857	India (Devaraj, 1981)
	TL	$1.54 * 10^{-2}$	2.814	India (Pilial *et al.*, 1993)
	FL	$1. 72 * 10^{-6}$	3.31	Oman (Dudley *et al.*, 1992)
	TL	$5.6 * 10^{-3}$	2.979	Saudi Arabian Gulf (Kedidi *et al.*, 1993)
	TL	$1.2 * 10^{-3}$	2.812	Red Sea (Kedidi and Abushusha,1987)
	FL	$1.1 * 10^{-2}$	2.85	Gulf of Aden, Yemen (Edwards *et al.*, 1985)
	FL	$1.06 * 10^{-5}$	2.94	South Africa (Torres, 1991)
S. guttatus	TL	$1.01 * 10^{-2}$	2.86	India (Devaraj,1981)
S. lineolatus	TL	$4.39 * 10^{-3}$	3.037	male, India (Devaraj, 1981)
	TL	$4.17 * 10^{-3}$	3.044	female, India (Devaraj, 1981
A. solandri	FL	$2.51 * 10^{-6}$	3.19	South Africa (Torres, 1991)

S. guttatus

Based on gonad index and ova diameter, Devaraj (1987) reported an extended spawning period from January to August, with a peak in April-May in the Gulf of Mannar and Palk Bay, south coast of India.

S. lineolatus

Devaraj (1986) carried out an investigation of *S. lineolatus)* in the Gulf of Mannar and Palk Bay similar to that of *S. commerson*, and concluded that the spawning season extends from January to July.

A. solandri

There is very little information on the spawning behaviour of *A. solandri.* Fish in different maturity stages are frequently caught at the same time, and therefore spawning appears to extend over a long time period in a season (Anon., 1995a).

Spawning behaviour

Devaraj's (1983, 1986, 1987) reproductive studies on the three *Scomberomorus* species indicated the occurrence of three batches of ova of different ripeness, and that spawning occurred during three successive periods in a year. For *S. commerson,* each year-class was composed of one weak brood produced in January-February, a dominant brood during April-May and another weak brood in July-August. For *S. guttatus, the* corresponding frequency of occurrence was January-February, April-May, and August; and for *S. Lineolatus,* it was January-early March, mid-March-May, and late June-July.

McPherson (1993) reported that the Queensland stock of *S. Commerson* spawned in the late afternoon.

Devaraj (1987) observed that the Gulf of Mannar stock of *S. guttatus* spawned around the full moon period during the spawning period.

Spawning Areas

Devaraj (1983) reported the landings of spawners of *S. commerson* by shore seines at Pudumadam Cove and the Gulf of Mannar on the south Indian coast. He also observed no ripe fish in drift nets set at 15-80-m depths during the spawning period. *S. commerson* in Oman waters appear to spawn in lagoons and fjords along the coastline of the Gulf and the northern Gulf of Oman (Anon., 1995b). Large *S. commerson* migrate into the Jizan trawl area in the Red Sea during June and July, apparently for spawning (Oakley and Bakhsh, 1989). Thus, it is probable that the coastal areas of the Gulf and the Red Sea serve as the primary spawning areas for *S. commerson.*

S. guttatus appears to spawn in areas between 20 and 60 m depth in the northern Gulf of Mannar (Devaraj, 1987).

Devaraj (1986) also reported that *S. lineolatus* spawned in inshore waters up to a depth of 25 m along south Indian coasts.

Size and Age at First Maturity

The minimum mature length ranges from 55 to 80 cm FL (approximately 1 year) for female *S. commerson,* from 40 to 52 cm total length (TL) (approximately 1-2 years) for S. *guttatus,* and 70 cm TL (1-2 years) for *S. lineolatus* in the Indo-Pacific region (Table 2). Fifty percent of the fish appear to mature over 2 years of age (see Dudley, *et al.* (1992) for *S. commerson*).

Fecundity

Fecundity (Fc) increased with age in the three *Scomberomorus* species in the Indian waters. Devaraj (1983) established the following linear equation relating absolute fecundity (*i.e.*, total number of ova spawned by a fish in a season) to the total length (TL in mm) of mature *S. commerson*:

$$Fc = -2273 + 3.5793 * TL$$

Dudley *et al.* (1992) used this relation on *S. commerson* of Oman and concluded that Fc increased from 590,000 eggs at age 1 year (80 cm FL) to 1,500,000 at age 2 years (110 cm FL). For *S. guttatus,* Fc increased from 385,000 eggs at age 2 years to 1,100,000 eggs at age 4 years; and for *S. lineolatus,* Fc increased from 559,000 eggs at age 2 years to 2,143,000 eggs at age 4 years (Bal and Rao, 1990). For *A. solandri,* maximum Fc was estimated to be 6,000,000 eggs for a female of 131 cm FL (Collette and Nauen, 1983).

Nursery Areas

Larvae of *S. commerson* are found in the coastal and Great Barrier Reef lagoon regions off Townsville, Queensland (Jenkins *et al.*, 1984). Pelagic eggs and larvae of S. *commerson* and *S. guttatus* have been recorded in the inshore waters off Madras and the Gulf of Mannar (Bal and Rao, 1990).

Small *S. commerson* (20-40 cm) were found in the R/V *Majid* trawl survey catches in July and September 1978 in the southeastern Gulf (Sivasubramanium, 1981). Significant quantities of *S. commerson* were caught in shrimp trawl survey catches in Bahrain during January and June to August 1980/81 (Abdulqader, 1988). It is likely that the sizes of these fish were small. Small fish (30-60 cm) have been caught close to the shore in the Musandum and Batinah region in Oman (Anon., 1995b). Thus, there is a possibility that a part of the *S. commerson* stock caught in Oman waters spawned and grew through their younger stages in the Gulf before migrating south to the Arabian Sea (Anon., 1995b). Oakley and Bakhsh (1989) observed large numbers of small *S. commerson* in the Jizan trawl ground in the Red Sea in winter months. This suggests that coastal areas in the Red Sea are likely to be the nursery areas for sub-stocks in the western Arabian Sea.

Sex Ratio

The sex ratio of the *S. commerson* population in Indian waters and the eastern Arabian Sea is approximately 1:1 (Bal and Rao, 1990; Anon., 1995b). The sex ratio of *S. commerson* in Oman waters is approximately 1:1 (Anon., 1995b). However, among the spawners and larger fish of *S. commerson* and all sizes of the other two *Scomberomorus* species, the sex ratio is in favour of females (Bal and Rao, 1990).

FISHERIES

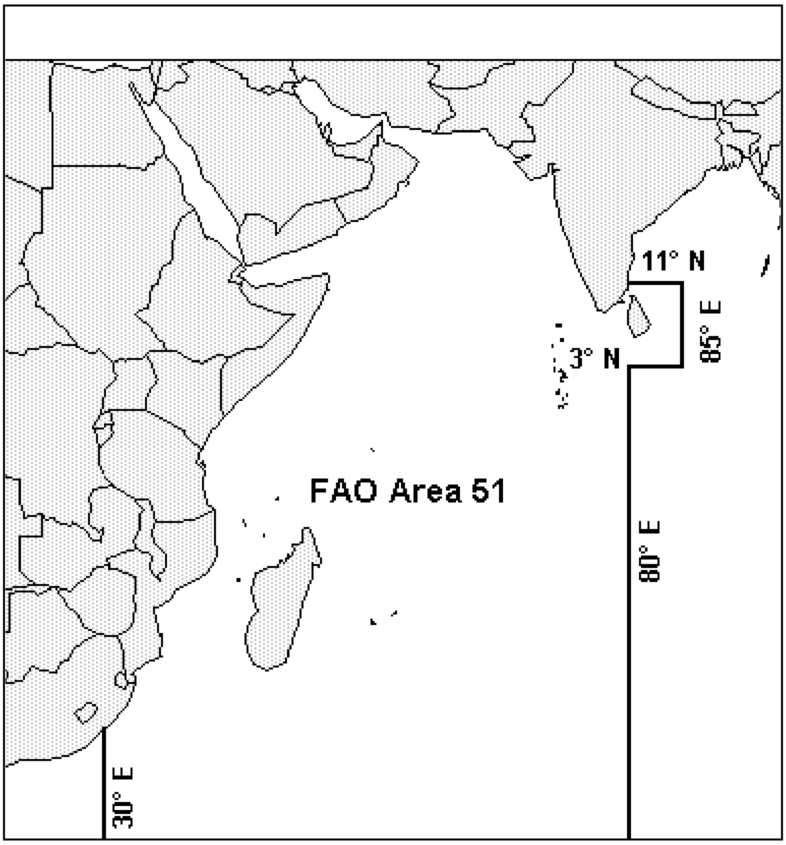
Catch

In 1993, *S. commerson* was the major component (71.8%) of the total seerfish landing in Area 51, followed by *S. guttatus* (27.4%), *S. lineolatus* (0.8%), and A. *solandri* (0.05%) (Table 1). One should be cautious about the landings by species given in Table 1 because catch data from some countries (*e.g.*, Saudi Arabia) have not been documented and most of the countries have reported the catch under one species name. It is very likely, therefore, that species of minor commercial importance either have been not reported, under-reported, or reported as the major species. For example, Oman and Sri Lanka have reported only *S. commerson,* although there is evidence to indicate that other species are also landed (Fouda and Hermosa (1993) and Siddeek, *et al.* (unpub. ms.) in Oman; Dayaratne (1989a) in Sri Lanka).

In 1993**,** India (with 28,845 metric tons (t)) topped the list of nations harvesting seerfish (a common English name for all four species; see Table 3 for different names used in different countries), followed by Pakistan (12,252 t), Iran (5,963 t), U.A.E. (5,630 t), Sri Lanka (3,769 t), Oman (3,148 t), and Yemen (2,743 t). Among the past major contributors to seerfish landings, Oman topped the list in 1985 and 1987-1989, but thereafter landings there dropped precipitously. This is not the case for other major seerfish-producing nations. Indeed, some of those countries maintained their annual landings at a steady level and some even increased their catches in 1993 (*e.g.*, India, Pakistan, and Iran) (Table 1).

Figure 3 shows the catch trends of *S. commerson* in Oman and Iran in relation to the total catch trend in all the nations bordering Area 51, as well as only those nations bordering the Gulf and the Gulf of Oman (*i.e.*, Iran, Kuwait, Bahrain, Qatar, U.A.E., and Oman (Saudi annual landings are not considered because they are not included in the FAO statistics report.)). The Oman catch continued to decline after the 1988 peak, whereas the Iranian catch increased systematically until 1993. Thereafter, in 1994 the Iranian annual catch in the Gulf and the Gulf of Oman declined to 3,463 t (Anon., 1995c). Since 1991, the total catch in Area 51 has increased and the total catch of those nations bordering the Gulf and the Gulf of Oman also showed a slight increase. Given the constant production trends in Yemen and U.A.E. (Table 1), and an increasing production trend in Iran until 1993, one finds it difficult to justify the precipitous decline in Oman's annual landings under the assumption of a greater degree of stock mixing among neighbouring countries. On the other hand, this decline can better be explained if the bulk of the Oman catches come from the resident stock whose spawning migration does not extend beyond the northern tip (Musandum) and the southern end (Salalah) of Oman, and the whole stock is confined to Oman territorial waters. Under these circumstances growth and perhaps recruitment overfishing may have caused this decline, because in recent years the declining landings have been associated with the

Figure. 1. *FAO Area 51 (Source FAO, 1994)*



occurrence of a greater proportion of small fish (Anon., 1995b). At this point the author wishes to caution the readers that these explanations are valid only if the reported country statistics are comprehensive and accurate.

Species composition of seerfish in the catches at selected stations on the west coast of Sri Lanka in 1987 was *S. commerson* 55-96%, *A. solandri* 3-45%, *S. guttatus* 0-2%, and *S. lineolatus* 0-1% (Dayaratne, 1989a). Pillai *et al.* (1993) estimated the average species composition in the 1981-1992 catches of seerfish in the west coast of India to be *S. commerson* 54%, *S. guttatus* 45%, *S. lineolatus* 0.7%, and *A. solandri* 0.3%. A large percentage of *A. solandri* are landed by the troll fishery in the Lakshadweep Islands. In Iran, *S. commerson* (ca. 60%) and *S. guttatus* (ca. 40%) were the prime contributors to the seerfish landings during 1981-1992 (Firoozi, 1993). The 1994 catch composition on the Iranian coast of the Gulf and the Gulf of Oman was *S. commerson* 69.6% and *S. guttatus* 30.4% (Anon., 1995c).

Fishing Season

In Sri Lanka, the fishing season for seerfish extends from June to October. The fishing season on the Indian coasts follows the monsoon pattern, from October to May on the west coast, and from March to October on the south coast. The fishing season in Pakistan is also somewhat tied to the monsoons, from March to May and September to January. In Iran, the fishing season is year-round. In Oman it is from September to April, following the southwest monsoon. In U.A.E., the fishing season is from February to June. On the Saudi Arabian Gulf coast, the fishing season is from October to the following June. On the Saudi Arabian Red Sea coast, the fishery is year-round. In Yemen, it extends from July to September and January to March . In Somalia, the fishing season follows the two monsoons, from March to May and September to November (IPTP, 1989; Firoozi, 1993; Bal and Rao, 1990).

Vessels and Gear

In Sri Lanka, 9-m class, 11-m class, and 5.5-6.1-m class mechanised fibreglass boats are used in the seerfish fishery. Fish are caught with large-mesh gillnets, troll lines, handlines, beach seines, and small-mesh gillnets. A single type or a combination of gear are used in a fishing trip. This is true for other countries as well. On the west coast of India, mechanised and unmechanised traditional craft (dug-out canoes and catamarans) of different size ranges are engaged in seerfish fishing. Gillnets, hooks and lines, and boat seines are employed. In Pakistan, large mechanised drift gillnetters are used to catch seerfish along with tuna. In Iran, mostly wooden boats and a smaller number of fibreglass boats are engaged in the seerfish fishery. The gillnet is the most popular gear. At present, a few industrial purse seiners also land seerfish in Iran (Anon., 1995c). In U.A.E., small outboard and large inboard mechanised vessels are engaged in the seerfish fishery. Gillnets and, less frequently, troll lines are used. On the Saudi Arabian Gulf coast, mechanised '*sambuks*' (long wooden dhows) and '*tarrads*' (fibreglass boats) are used in the seerfish fishery. On the Red Sea coast mechanised '*houris*' and '*sambuks*' are employed. Gillnets are popular, followed by troll lines. In Oman, fibreglass skiffs of 6-10 m size range and wooden launches of 10 m and larger sizes are employed in the seerfish fishery. These vessels use gillnets, troll lines, hand lines, and pen gillnets. Industrial trawlers also land small quantities of seerfish in Oman. In Yemen, small skiffs and large launches of wood or glass-reinforced plastic (GRP) are used in the tuna and seerfish fisheries. These vessels use troll lines, hand lines, longlines, gillnets, small purse seines, and ring nets (IPTP 1989; Anon., 1994, 1995b, 1995c).

Table 7. **Length-based estimates of annual total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation ratio (E) for *S. commerson* in FAO Area 51 and *A. solandri* in West Indies waters.**

Species	*Z*	*M*	*F*	*E*	*Remarks*
S. commerson	1.63	0.605	1.03	0.63	Sri Lanka, 1986-1987 data, mean Z from length converted catch curve and Wetherall methods, M by Pauly's regression (not multiplied by 0.8), F = Z-M, E=F/Z (Dayaratne, 1989b)
	3.288	0.78	2.508	0.76	India, 1989-1991 data, Z by length converted catch curve for 65-70 to 105-110 cm, M by Pauly's regression (multiplied by 0.8), F and E found as above (Pilial *et al.*, 1993)
	3.45	0.78	2.67	0.77	India, 1989-1991 data, F from length cohort analysis averaged over 65 cm and above, M and E estimated as above, Z =F+M (Pillai *et al.*, 1993)
	1.151	0.526	0.625	0.543	Oman,1987-1989 data, Z by length converted catch curve, M by Pauly's regression (not multiplied by 0.8)1 F=Z-M, E=F/Z (Dudley and Aghanashinikar, 1989)
	1.78	0.384	1.396	0.784	Oman, same data set same estimation methods with different growth parameters (Dudley and Aghanashinikar, 1989)
	1.592	0.36	1.23	0.77	Saudi Arabian Gulf, 1986-1992 data, Z by length converted catch curve for 95-160 cm, M by Pauly's regression (multiplied by 0.8), F=Z-M, E=F/Z (Kedidi *et al.*, 1993)
	0.758	0.36	0.398	0.525	Saudi Arabian Gulf, 1986-1992 data, F from length cohort analysis averaged over 45-160 cm, M by Pauly's regression (multiplied by 0.8) (Kedidi *et al.*, 1993)
	1.04	0.46	0.58	0.56	Red Sea, 1985-1986 data, Z by Jones and van Zalinge's method; M, F and E estimated as above (Kedidi and Abushusha, 1987)
		0.7			Oman and Red Sea, guessed value (Bertignac and Yesaki, 1993)
		0.5, 0.6			Oman, guessed values (Dudley *et al.*, 1992)
		0.77			M by Rikhter and Efanov's method assuming a 50% maturity age of 2 years (this report)
A. solandri	1.35	0.57			St Lucia, West Indies; 1982-1983 data, Z by length converted catch curve averaged for 1982 and 1983, M by Pauly's regression (not multiplied by 0.8) (Murray and Sarvay, 1987)

Among all gear, the gillnet accounts for the largest share of the catch in most countries. Two mesh size ranges are common, and are used to catch small and large seerfish. The stretched mesh size of small-mesh nets ranges from 3 to 9 cm, while the corresponding range for the larger-mesh nets is 10 to 15 cm. In some countries (*e.g.*, Sri Lanka) small-mesh gillnets are used for small pelagic fish, and catch juvenile seerfish incidentally. On the other hand, in some other countries (*e.g.*, Oman) consumers prefer medium-size (approximately 60-90 cm FL) fish over larger ones, and fishermen use specific mesh sizes (*e.g.*, 8 cm in Oman) to catch them during the season.

In Area 51, the bulk of the seerfish catches come from the artisanal fleet. However, company- or foreign-owned industrial longliners, trawlers, and purse seiners also operate in the EEZ of some countries (*e.g.*, Iran, Oman and Somalia), and harvest significant quantities of seerfish.

Economic Importance

Seerfish are harvested as food fish as well as game fish (Anon., 1995a). In Area 51, however, they are largely exploited by the artisanal fishing fleets as food fish. Seerfish are marketed locally in fresh, iced, frozen, and salted and dried form. Fresh fish are also exported to neighbouring countries by land. The cooked meat of seerfish is light in colour and meaty in taste. Therefore, it is a preferred species in all countries in Area 51 (Anon., 1995a). In Oman, the average export values per kg of seerfish and grouper (the two most popular fish in the Middle East) in 1993 were US$ 2.94 and 1.99, respectively. Thus, the price of seerfish far exceeds the next preferred fin-fish (Anon., 1994).

RECRUITMENT TO THE FISHERY

Juvenile *S. commerson* of 9-45 cm FL are caught by small-mesh gill nets on the west coast of Sri Lanka in July-August (Dayaratne, 1989b). Small size (<45 cm FL) *S. commerson* are found in gillnet catches on the west coast of India (Pillai *et al.*, 1993). In the Gulf off Busher (Iran), a significant number of fish in the 34-40 cm FL range were found during October-January in the 1993-1994 catches (unpublished data submitted at this workshop). In U.A.E., fish as small as 25 cm FL are seen in September catches (IPTP, 1989). Length measurements of catches made in Oman fish markets during September- December 1987-1992 indicated a significant number of fish falling in the 30-60 cm FL range (Dudley and Aghanashinikar, 1989; Anon., 1995b).

Bertignac and Yesaki (1993) considered a mean recruitment age of 0.25 years (approximately 48 cm FL) for the Oman and Saudi Arabian *S. commerson* populations for stock assessment.

AGE AND GROWTH

Two approaches have been followed in determining the age and growth of seerfish. The first approach is length-frequency analysis. Two techniques are popular. First, the Electronic Length Frequency Analysis (ELEFAN) program has been used to fit the von Bertalanffy growth curve on seasonal length-frequency distributions without considering the age composition (*e.g.*, Dudley and Aghanashinikar, 1989). Second, length frequencies have been transformed to ages either by Petersen's method (*e.g.*, Devaraj, 1981) or by standard statistical procedures (*e.g.*, Bhattacharya method, Bertignac and Yesaki, 1993; Kedidi *et al.*, 1993) and then the von Bertalanffy growth curve has been fitted to modal lengths (mean length at age) to estimate the growth constants (L_∞, K and t_o) (Devaraj, 1981; Dayaratne, 1989b; Dudley *et al.*, 1992).

The second approach is the otolith microstructure study. Otolith microstructure studies have been undertaken to determine age, and thereafter a growth curve has been fitted to mean length at age to estimate growth constants. Those who did the otolith microstructure studies analysed the length-frequency data as well to obtain an independent set of growth parameter estimates (Table 4). The use of two independent approaches to determine growth estimates is always preferable to a single approach (Gulland and Rosenberg, 1992). However, very often the two sets of estimates do not match (Devaraj, 1981; Dayaratne, 1989b; Dudley *et al.*, 1992).

Length-frequency analyses using various methods produce a wide range of growth parameter estimates for the same data set, and lead to conflicting management decisions (*e.g.*, Dudley *et al.*, 1992). For *S. commerson*, the L_∞ estimate varied from 131.2 cm FL to 230.3 cm FL. The K (growth rate) value varied from 0.12 to 0.78 (Table 4). A single set of growth parameter estimates is available for *S. guttatus,* female *S. lineolatus,* and male *S. lineolatus* within Area 51, and for *A. solandri* outside the study area. The K values are within the same range as those for *S. commerson* (Table 4). Since in most cases the natural mortality coefficient (M) is estimated using K by Pauly's multiple regression equation (Pauly, 1980), and the length-converted catch curve and recruitment pattern analyses are also done using the estimated growth parameters, errors in growth parameter estimates will introduce errors in those parameters as well and hence the overall assessment. One should be aware of the behaviour of a non-linear model such as the von Bertalanffy growth equation before using it. A multi-parameter non-linear model is likely to provide different sets of plausible parameter estimates for a given data set (Sparre *et al.*, 1989). Therefore, unless a researcher explores all the possible ranges of values for the parameters or has independent estimates of some of those parameters (for example L_∞), he is very likely to end up with a sub-optimal set of results. Furthermore, confidence limits are needed for the estimates. The ELEFAN suite of programs assumes no distribution pattern on length frequencies (*i.e.*, ELEFAN uses a non-parametric method) to estimate growth parameters, and does not provide confidence limits for the estimated values. This drawback can be overcome when many years of length-frequency data are available; then, one can estimate a separate set of results for each year's (or combination of years') data, and hence compute confidence intervals.

Highly migratory fish, such as seerfish, pose an additional problem when using length frequencies for growth estimation. Modal progression may show negative growth because of mismatches in the sequential modes from a cohort (*e.g.*, Kedidi *et al.*, 1993). This can be overcome by matched sampling if the exact migration pattern is known (see Spare *et al.* (1989) for details), which is very unlikely unless an extensive tagging program is undertaken. More generally, data from neighbouring countries which cover the stock migration route, may be combined to discern the modal progression of cohorts and hence derive reliable growth parameter estimates. This emphasises the need for joint assessment of the shared stock.

Otolith ageing and length-frequency analysis have provided mean length-at-age for *Scomberomorus.* Mean length-at-age for the same species in different waters differed (Table 5). This may be due either to the existence of different growth rates in different habitats or to errors in interpreting otolith ages as a result of the occurrence of false annuli as well as estimating optimal growth parameter values. The growth rate of S. *commerson* is high until they are two years old, thereafter it declines (Dudley *et al.*, 1992).

Devaraj (1981) noted two ring formations at a six- month interval in the otoliths of Indian *Scomberomorus.* Ageing studies have indicated that *S. commerson* live up to 7 years or more. The other two *Scomberomorus* species (*S. guttatus and S. lineolatus*) appear to have similar lifespans. The maximum length of *S. commerson* found in the region ranged from 193.6 cm TL to 230 cm FL. The maximum length of the other species were: *S. guttatus* 70.5 cm TL, *S. lineolatus* 98 cm TL, and *A. solandri* 200 cm FL (Table 4).

Many researchers reported growth variation between sexes. Females dominate the large fish group. However, most of the growth studies ignored this aspect and growth estimates were done for the combined sexes (Devaraj, 1981; Dayaratne, 1989b; Dudley *et al.*, 1992).

LENGTH-WEIGHT RELATIONSHIP

The b parameter values in the weight-length model, W = a L^b are close to 3 for the four species in Area 51, indicating isometric growth (Table 6). This is expected for fusiform fish.

MORTALITY

Mortality rates are available only for *S. commerson* in the study region. The majority of the mortality estimates are based on length-frequency data. The length-converted catch curve and Jones and van Zalinge methods (Sparre *et al.*, 1989) have been used for total mortality (Z) estimation. Pauly's (1980) multiple regression equation is used with growth parameter values to estimate natural mortality (M). Since *Scomberomorus* species are considered schooling migratory fish, some researchers (*e.g.*, Kedidi and Abushusha, 1987; Kedidi *et al.*, 1993; Pillai *et al.*, 1993) have multiplied the M values by 0.8 to reduce bias. From the average annual Z and M, average fishing mortality (F) and exploitation ratio (E) have been estimated. Length- and age-based cohort analyses are also used to estimate length- and age-specific fishing mortality (F) and stock size (*e.g.*, Bertignac and Yesaki, 1993; Pillai *et al.*, 1993; Kedidi *et al.*, 1993). Table 7 provides average mortality and exploitation ratio estimates determined for S. *commerson* in Area 51, and Z and M estimates for *A. solandri* in West Indies waters. Average fishing mortality determined by the catch curve method (*i.e.,* F = Z-M) for fully-recruited fish indicates over-exploitation in many countries in the study area. On the other hand, mean F estimated by length-cohort analysis for the young and fully-recruited fish indicates near optimal exploitation (*e.g.*, Kedidi *et al.*, 1993).

The length-converted catch curve method assumes a steady-state condition (Gulland and Rosenberg, 1992). Furthermore, it considers a size range above full recruitment size for Z estimation. Gillnet selectivity coupled with migration often inflates Z for this length range, and hence F and E. For a declining (or increasing) stock, the steady-state assumption is likely to be violated. Moreover, because growth parameters are used in estimating the length-converted catch curve, the errors in growth estimates (resulting from migration) will bias the total mortality estimates. The results for Oman (Table 7) clearly show that the mortality estimates are dependent on growth parameter values. Length-cohort analysis also has the same deficiency. Thus, one cannot be certain about the real status of exploitation of a migratory stock through length-based analyses unless adequate care has been taken in determining the growth parameters.

In the case of length- or age-based cohort analysis only one M value, which is either estimated from growth parameters using Pauly's (1980) equation (*e.g.*, Kedidi *et al.*, 1993, Pillai *et al.*, 1993) or guessed (Bertignac and Yesaki, 1993), has been used. Errors in M will cause errors in F and stock size estimates. This is also true for the E estimate from length-converted catch curve analysis. Since M is a difficult parameter to estimate for a heavily-exploited stock (Siddeek, 1991) such as seerfish in the study region, independent methods (*e.g.*, total mortality *vs.* effort regression, Richter and Efanov's formula (Sparre *et al.***,** 1989)) should be used to evaluate a plausible M value or preferably a set of plausible values. Dudley *et al.* (1992) rightly used a range of M values (Table 7) to explore the yield under different fishing and growth patterns. I estimated an annual M value of 0.77 (Table 7) using Richter and Efanov's formula assuming the 50% maturity age of *S. commerson* to be 2 years (see section 2.6.4). This estimate is close to those used by Bertignac and Yesaki (1 993) and Pillai *et al.* (1993). As rightly pointed out by Bertignac and Yesaki (1993), independent estimates of either stock size or index of stock size (*i.e.*, catch per unit of effort (CPUE)) are required over the same time period to confirm cohort analysis results.

GEAR SELECTIVITY

A fish is retained in a gillnet when it penetrates the mesh beyond its gill covers but is blocked at or before its maximum girth. This implies that a fish is caught in a gillnet of particular mesh size if the head girth is smaller but its maximum girth is larger than that particular mesh perimeter. Ehrhardt and Die (1988) using a gillnet selection probability model which incorporated the values of head girth, maximum girth, and elasticity of the netting material, found that as fish grow the selection range of the gear also increases. They further noted that the selectivity of Spanish mackerel in Florida changes as the condition of the fish changes with the onset of maturity.

No experimental gillnet selectivity study has been reported in Area 51. Length-frequency data have often been used to estimate mean length at first capture and selectivity. Analyses have indicated that the 50% selection length of *S. commerson* ranges from 30 to 65 cm TL for small to large gillnet mesh sizes used in the fishery (Pillai *et al.*, 1993; Kedidi and Abushusha, 1987).

Maximum girth data have been used as a basis for recommending mesh regulations. Dudley *et al.* (1992) established the following linear relationship between girth and fork length for *S. commerson* in Omani waters:

$$0.5 \text{ girth (cm)} = 0.217 \text{ FL (cm)} - 1.6$$

For a given fork length, one can estimate the girth using the above formula. A stretched mesh size equivalent to half of this girth will, in general, not allow the fish to pass through. Therefore, an appropriate mesh size can be determined, using the above formula, to release fish of below any particular size. The girth factor (maximum girth/total length) can also be used to find the selection factor, and then the mean selection length for a given mesh size (Kedidi and Abushusha, 1987).

STOCK ASSESSMENT

Exploitation ratio, yield-per-recruit and length- and age-based cohort analyses have been used to assess the state of seerfish stocks and to make management recommendations in Area 51. *S. commerson* has been heavily investigated because it is the prime species in Area 51.

Pillai *et al.* (1993) used length-cohort analysis and the Thompson and Bell model in the stock assessment of *S. commerson* on the Southwest coast of India. They concluded that to reach the maximum sustainable yield (MSY) of 7,649 t the current (*i.e.*, 1989-1991 period) exploitation rate should be reduced by 59%.

Bertignac and Yesaki (1993) used the Bhattacharya method to construct the catch-by age table for the *S. commerson* stock in Oman and the Red Sea. Then they used virtual population analysis (VPA) to estimate age-specific fishing mortality (F) and stock size (especially recruitment). The F derived from VPA were used in the Thompson and Bell model for short-term predictions of yields. The VPA indicated that 1985-1987 cohorts were strong and contributed to high catches in 1987 and 1988. The cohorts after 1987 were weak, causing the drop in catches.

Gubsh (1994) carried out a length-cohort analysis on the 1988 -1993 data on S. *commerson* in Oman. He also used the Thompson and Bell method to forecast future yield and mean biomass under different sizes at first capture and F values. His results showed that the current F was in excess of the optimal level and the mean biomass could be increased substantially by increasing the size at first capture.

Dudley *et al.* (1992) simulated yields using Ricker's model for various fishery scenarios for the *S. commerson* stock in Omani waters (this model used the growth estimates derived from February 1987- January 1990 data). They observed that protecting young fish during their entire first year would increase the yield by 30%. To achieve this, they recommended enforcing a minimum mesh size of not less than 14 cm (5.5"). They used the girth-length formula to derive this mesh size.

Kedidi *et al.* (1993) applied yield-per-recruit and length-cohort analyses to 1986-1992 data for the Saudi Arabian Gulf stock of *S. commerson* and obtained average exploitation values of 0.547 and 0.525, respectively, which are close and indicate optimal exploitation. They cautioned about this finding because migration may have affected the growth parameter estimates as well as the fishery.

Based on the yield-per-recruit analysis of the *S. commerson* stock in the Jizan area in the Red Sea, Kedidi and Abushusha (1987) concluded that no increase in yield was possible from changing the exploitation level while keeping the mean length at first capture at 50 cm TL.

Available stock assessment results on *S. commerson* in Area 51 indicate that *S. commerson* is heavily fished in all countries except the Saudi Arabian Gulf and the Red Sea.

RECOMMENDATIONS

Fisheries Data Collection

The declining seerfish yield observed in Oman, in contrast to those in the neighbouring countries which show a constant yield or even increasing yields, highlights many issues on fisheries statistical data collection procedures. For example, are the stocks in Oman different from the others? Are the country statistics comprehensive and accurate?

Although at least three species of *Scomberomorus* are landed in all the countries bordering Area 51, only *S. commerson* is reported by many of them. Moreover, effort by species, area, and gear are missing in many countries. We should not demerit the use of catch and effort data. Indeed, Hilborn and Walters (1992) argue that stock assessment based on biomass dynamic models (for example, the Schaefer model), which uses only catch and effort data, provide similar management conclusions to those derived by the age-structured models. CPUE statistics can be used to derive total mortality values which can be compared with the length-based estimates. Due to inherent problems with ageing of tropical fish, as well as with length-based methods, we should direct a greater effort to obtaining comprehensive and accurate catch and effort data on seerfish for use in biomass dynamic model assessment.

Biological Research

Apart from limited length, otolith, and catch-and effort data analyses, nothing concrete is known about the life history of seerfish in many countries. Spawning areas, larval and juvenile distribution, and adult migration are largely not investigated in many countries in the study region. Only a few countries (*e.g.*, India (Devaraj, 1983) and Saudi Arabia (Kedidi and Abushusha, 1987; Kedidi *et al.*, 1993)) have attempted to investigate the spawning seasons and spawning frequencies by systematic gonad sampling. Systematic stomach sampling for feeding investigation has also not been undertaken (or not reported) in almost all the countries in Area 51. After reviewing Oman seerfish research activities, Moore (1994) recommended undertaking comprehensive research studies on the life history pattern, the fishery, and economics and social aspects for preparing a sustainable management plan to improve the seerfish fishery.

Ageing of tropical fish poses many problems because of either inconspicuous ring formation on the otolith or on any hard part of the fish or age validity. The length-based stock assessment models are also beset with many problems because length is not linearly related to age. Moreover, protracted spawning, gillnet selection and migration do not help to produce clear length modes and modal progressions, respectively, for valid growth estimation. Growth estimates by otolith (or any other hard structure) ageing and by length-frequency analysis often conflict (Dudley *et al.*, 1992). Therefore, research and facilities

Figure. 2. *Relative Frequency Histogram of S. commerson Musandam, Oman, April 1995 (Source: Siddeek, Fouda and Hermosa (Unpublished))*

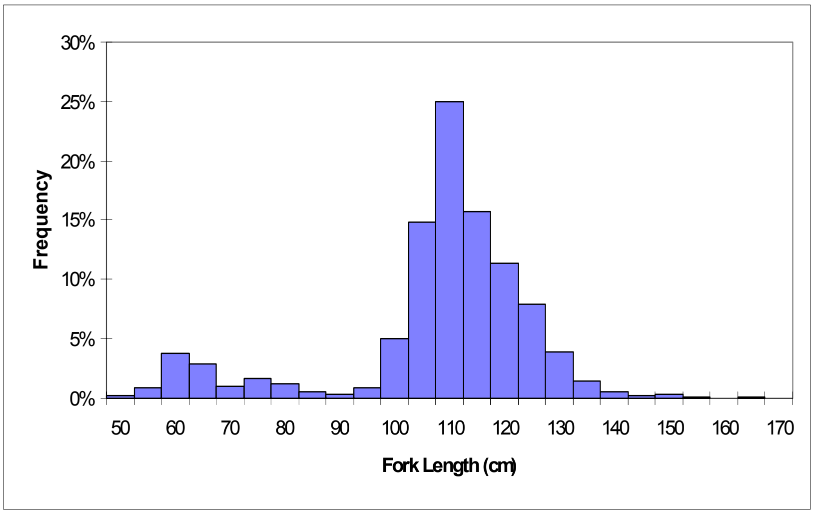
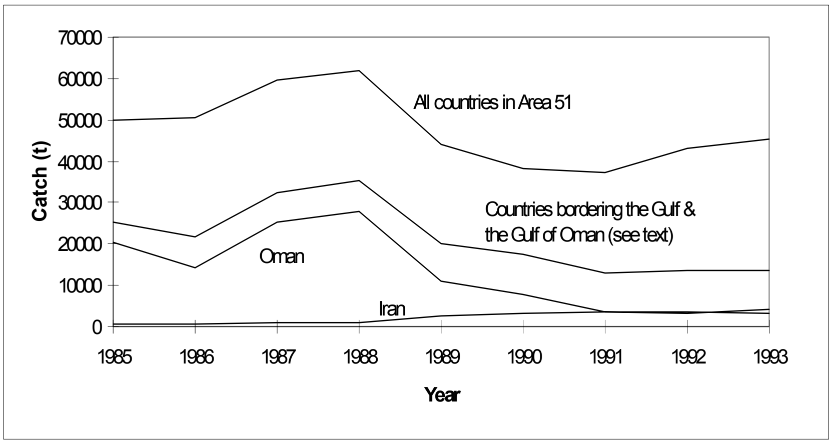


Figure. 3. Seerfish Catch in the FAO Area 51 (Source: FAO Yearbook, Fishery Statistics-Catches and Landings, Vols. 75 & 76)



should be focussed towards sorting out ageing problems. Sharing the common problems on ageing tropical fish with others in or outside the region should be an important research objective.

Research on unit stock identification and migration is needed for fisheries and biological data separation by region for stock assessment. Reliable estimates of growth and fishing mortality parameters are required for correct stock assessment advice. Even though it is difficult and expensive, the tagging method is a useful tool for stock separation, migration, growth, and mortality studies. Tagging experiments have been undertaken on seerfish in a few places (*e.g.*, Queensland (McPherson, 1981); Southeast Louisiana (Fable *et al.*, 1987)). Fable *et al.* (1987) used internal anchor tags on handline-caught *S. cavalla* in Southeast Louisiana to determine their migratory patterns.

Investigations of a number of biological population parameters are needed for a comprehensive stock assessment. Ichthyoplankton investigation is required to identify spawning areas, spawning intensity and frequency, and egg and larval distribution by space and time; systematic gonad sampling is required for seasonal maturity investigation; and systematic stomach sampling is needed for seasonal food composition in the diets of various stages of fish.

Gear Selectivity Study

Various gillnets are used to catch seerfish along with other fish. In order to optimise and regulate the fishery, a gillnet selectivity study is needed.

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